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Atmospheric Chemistry and Physics Discussions



# *Interactive comment on* "Measurement of black carbon at Syowa station, Antarctica: seasonal variation, transport processes and pathways" *by* K. Hara et al.

**K. Hara et al.**

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Reply to Comments from reviewers

We would like to thank Dr. A. Stohl and an anonymous reviewer for helpful comments on the manuscript. Author's responses (preceded by R) to comments by Dr. A. Stohl (preceded by Stohl) and an anonymous reviewer (preceded by C2) are as follows;

**Stohl:** A clear plot showing this relationship (e.g., a scatter plot of BC as a function of wind speed) is missing.

**R:** We add plot of variation of wind speed at Syowa in Figure 6 showing seasonal variation of hourly-mean BC concentration. High BC peaks were observed in strong



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winds during the measurements. Although BC peaks did not appear in some strong wind condition, this may result from longer transport time as described in 4-2-3 and Figure 12.

**Stohl:** In the presence of a large amount of light scattering particles on the filter, signal from absorbing material can be significantly enhanced, thus biasing the data towards the high side. It is likely that sea-salt concentrations increase with wind speed which might explain the apparently measured increase of BC concentration. The supposed southward transport pathway would frequently be associated with the air mass being lifted and washout being very likely. Can the surface measurements even "see" such a transport of BC?

**C2:** In view of basically indirect BC quantification method and the outstanding contamination risk the authors need to clearly, (1) that their net signal definitely reflects the elemental carbon fraction and, (2) that it is representative for the background conditions and associated long-range transport. Generally, it is hard to conceive why this kind of BC should still hold information on its pathway though the vigorously mixed and intensively scavenged atmosphere between the continental source area and Antarctica.

**R:** As pointed out by Stohl, sea-salt particles are one of major aerosol particles at Syowa, Antarctica [Hara et al., 2004]. Higher concentration of sea-salt particles can lead to overestimation of BC concentration or absorbing coefficient. We made routine aerosol sampling for single particle analysis, basically once a week. In order to assess data quality of BC measurement in the present study, aerosol samples in higher BC concentration and lower BC concentration were analyzed with scanning electron microscope equipped with energy dispersive X-ray spectrometer (SEM-EDX). SEM-EDX analysis indicates that external mixtures of carbonaceous particles were presence in the aerosol sample of high BC concentration, whereas the external mixtures of carbonaceous particle were not obtained from the aerosol samples in lower BC concentration. Relative abundance (number fraction) of the carbonaceous particles



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in higher BC concentration was 8.4 and 0.09 % in coarse mode ($D_P$>2.0 $\mu$m) and fine mode (0.2<$D_P$<2.0 $\mu$m), respectively. Using the relative abundance and number concentration of aerosol particles simultaneously measured by optical particle counter, the number concentration of the carbonaceous particles can be estimated to 16 $L^{-1}$ in coarse mode and 757 $L^{-1}$ in fine mode. Assuming density of 0.7 $\sim$ 1.0 g $cm^{-3}$ for carbonaceous particles and spherical shape, mass concentration of carbonaceous particles (soot or elemental carbon) was estimated to 31.6 $\sim$ 45.2 ng $m^{-3}$. This range was coincident well with BC concentration (42.7 ng $m^{-3}$) measured by PSAP. Although higher aerosol particles can lead to overestimation of BC concentration as suggested by Bond et al. [1999] and Stohl's comment, this coincidence suggests that variation of BC concentration in the manuscript depend on the concentration of absorbing particles (carbonaceous particles) and that overestimation was insignificant or less. Furthermore, mineral particles were also observed in the aerosol samples. Considering very less source strength of mineral particles in the Antarctica, mineral particles and carbonaceous particles should be transported from the mid-latitudes (e.g., other continents). We add the description about this to section of 4-1. Procedures of aerosol sampling and single particle analysis were also added in section of "Measurements".

**C2:** Substantial short term BC increase indicate local artifact for the most part rather than distinct air mass transport properties.

**R:** When wind came from main area of Syowa to the observatory, local contamination prevents BC measurement at the observatory. Large emission source of BC in main area was diesel power generator. High temperature processes in diesel engine can release chain-like agglomerates of spherical particles (15 $\sim$ 30 nm) [e.g., Maricq et al., 2007]. However, external mixture of carbonaceous particles at Syowa had not chain-like agglomerate structure but compact aggregate structure as shown in Figure 5. The compact aggregate carbonaceous particles were not observed in the Arctic haze containing anthropogenic matters from industrial regions [Hara et al., 2003]. Thus, the compact aggregates of carbonaceous particles may not be emitted from the main area



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of Syowa. Indeed, presence of mineral particles supports long-range transport of BC from mid-latitudes.

According to Hagler et al. [2008], atmospheric BC concentration drop rapidly within first few kilometers of distance from the source. In their estimation (Hagler et al., 2008), distance from the source is approximately 10, 14, and 27 km to decrease to 1 ng $m^{-3}$ of BC concentration in the case of wind speed of 7.9, 4.5 and 1.2 m $s^{-1}$, respectively. Because strong wind comes from the direction of prevailing wind without local BC sources at Syowa as shown in Figure 4, local contamination from main area of the station can occur only under the condition of weak winds. Although BC can be dispersed from main area of Syowa in weak winds, weak winds lead to local contamination with very local scale. Hence, wind blowing for 1 $\sim$ 3 hours should be enough to transport air mass from "clean air sector" without local impact even in wind speed of 2 $\sim$ 5 m $s^{-1}$. Therefore, local anthropogenic impact can be negligible under the conditions of wind blowing from the direction ("clean air sector") with non-local contamination sources , at least, for a few hours. These disruptions were added to the text in our manuscript.

**Stohl:** I presume the station is located near sea level. The trajectory may be started much too high in order to be representative of the air masses sampled at the station.

**R:** We change the trajectory from 500 m and 1000 m in Figure 9. Routine radio sonde measurements and tethered balloon aerosol measurements (not shown in our manuscript) indicated that 500 m a.s.l. was upper boundary layer, so that we can discuss the air mass origin using the trajectory from 500 m a.s.l..

**Stohl:** I suggest that trajectories only during this episode are shown or at least highlighted.

**R:** Backward trajectory in the case of cyclone and blocking episode was merged with plots of geopotential height. Because we believe that trajectory plots need to compare pathway in each trajectory, Figure 9 remains in the manuscript.



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**Stohl:** The Syowa measurements are compared to measurements at Amsterdam Island and at other Antarctic stations. While the text describing this comparison is very long...

**R:** As your suggestion, we shortened the description to less than 1000 words. Essence of description was not changed.

**Stohl:** One important source of BC in the Antarctic atmosphere may be cruise ship by which tourists are being brought to Antarctica.

**R:** It is true that tourist cursing is operated in Antarctic regions during the summer. However, most of ship for tourists has been to Antarctic Peninsula close to South America. Because Syowa station is far from the other continents such as Africa and Australia, tourist ship did not come close to Syowa station. Therefore, we can neglect influence from tourist ship.

**Stohl:** The authors may be right that this indicates higher BC concentrations aloft, which are being brought down by strong katabatic winds. However, is there a stretch of open sea from the direction the katabatic winds normally arrived from?

**R:** Diurnal variation of katabatic winds was observed only in stable conditions (not storm condition). The katabatic winds come from the continent in the condition. The diurnal variation of BC concentration was observed from end October till end February. As mentioned above, higher concentration of solid particles can overestimate BC concentration. Sea-salt concentration in aerosols, however, decreased to $\sim$5 nmol $m^{-3}$ during the summer, especially 2 $\sim$ 3 nmol $m^{-3}$ in January and February (Hara et al., 2004), whereas sulfate concentration increased by ca. 3 nmol $m^{-3}$ at Syowa (Osada et al., 1998). Also, single particle analysis indicated that $H_2SO_4$ particles were dominant at Syowa and continental area during the summer (Yamato et al., 1987; Hara et al., 1995). Thus, contribution of sea-salt particles may decrease in the air in katabatic winds coming from inland area to coastal area. As poor correlation ($R^2$=0.36 in $D_P$>0.3 $\mu$m and $R^2$=0.35 in Dp>2.0 $\mu$m) between the number concentration and BC



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concentration was obtained during the period in Figure 13 (1 $\sim$ 10 November 2006), sea-salt particles make insignificant or less impact on BC measurements in the summer. Hence, diurnal variation of BC concentration may result from the variation of absorbing particles. These disruptions were added to the text in our manuscript.

**Stohl:** Have parallel measurements been done with these two instruments?

**R:** For intercomparison of BC measurement, both instruments were simultaneously operated for 2 weeks in January 2005. BC data in PSAP matched well with that in aethalometer during the simultaneous operation. This description was added in the text.

Other minor points were also corrected in text and figures in the revised manuscript.

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